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SUMMARY

The effects of cyclic and of continuous immersion in heptane, toluene, and SR-6, a test fuel, on the weight, dimensions, and flexural properties of 19 samples of laminated plastics were determined. No one sample exhibited smaller changes than all other samples in all properties for all fuels and for both cyclic and continuous immersion.

The best weight and dimensional stability in the cyclic test was shown by a glass-fabric unsaturated-polyester laminate. The changes in flexural strength as well as in modulus of elasticity were losses in the majority of cases after the cyclic and the continuous immersion tests.

The unsaturated-polyester laminates varied widely among themselves in regard to the magnitude of the change in a given property after an immersion test.

INTRODUCTION

Information regarding the effects of immersion in various fuels on the properties of laminated plastics is needed to evaluate these materials for use on aircraft and to prepare specifications for such materials as are found suitable for this purpose.

The present report presents the results of tests made to determine the effects of cyclic and continuous immersion in three fuels on the weight, dimensions, and flexural properties of 19 representative laminated plastic materials. The cyclic immersion test involved alternate 24-hour periods of fuel immersion and air-drying. The continuous immersion test involved immersion in the fuels for different periods of time between 7 and 360 days. Both types of tests were carried out at only one temperature, 77° F.

In view of the variability in properties to which the materials herein examined are generally subject, no attempt has been made to draw general inferences regarding the superiority of one or more of these materials relative to the others.

This investigation, conducted at the National Bureau of Standards, was sponsored by and conducted with the financial assistance of the National Advisory Committee for Aeronautics.

MATERIALS AND FUELS

The materials used in this investigation included commercial grades such as grade C, L, and AA phenolic laminates and several experimental materials of interest for aircraft application. The experimental samples were as follows: A number of unsaturated-polyester-resin laminates reinforced with glass and cotton fabrics, a cotton-fabric melamine-resin laminate, a high-strength-paper phenolic-resin laminate, a rayon-fabric phenolic-resin laminate, two experimental phenolic-resin laminates made with high pressure and low pressure, respectively, using the same grade C cotton fabric as filler, and a paper-base lignin laminate.

The materials are described in detail in table I. They were obtained in the form of sheets approximately 1/8 inch thick.

The fuels used were heptane (an aliphatic hydrocarbon), toluene (an aromatic hydrocarbon), and SR-6, a representative aircraft test fuel (a blend of aliphatic and aromatic hydrocarbons). The heptane used was a commercial n-heptane and the toluene was a technical toluene; both were supplied by the Phillips Petroleum Company. The SR-6 used was a mixture of di-isobutylene (60 percent), toluene (20 percent), xylene (15 percent), and benzene (5 percent), and 0.2 pound of aviation gasoline inhibitor per 1000 gallons, supplied by the Standard Oil Co. of New Jersey. The inhibitor consisted of 50 percent of n-butyl-p-aminophenol, 30 percent of isopropyl alcohol, and 20 percent of anhydrous methanol, and was added in order to hinder the oxidation of the di-isobutylene, a diolefin, with consequent gum formation.

TEST PROCEDURES

Specimens

The dimensions of the test specimens were 1 inch by 3 inches by the thickness of the sheet. The specimens were machined on a surface grinder with tap water as a coolant. The length and width were kept to within ±0.005 inch of the above dimensions. One surface of each sheet was arbitrarily designated as the reference surface. The specimens of the cloth laminates were cut so that the direction with the greater number of threads per inch in the reference surface was lengthwise. As all the paper laminates were cross-ply materials, the lengthwise direction of these specimens was arbitrarily taken parallel to one edge. The weight of the specimens varied from approximately 7 to 12 grams.

The specimens which were to be immersed were conditioned for 48 hours at 77° F and 50-percent relative humidity prior to starting the tests.

Weight and Dimensions

The weight was determined to the nearest milligram. The length was measured to the nearest 0.001 inch, and the width and thickness to the nearest 0.0001 inch. The length was measured at two places, and the width and thickness at three places. The changes in weight and dimensions were determined with two specimens of each material. The changes in the length and width columns presented in the tables were determined by taking the mean of the average length changes and the average width changes.

Flexural Properties

The flexural tests were made in accordance with Method No. 1031 of reference 1, using the 1200-pound scale of the 2400-pound-capacity hydraulic testing machine shown in figure 1. The flexural apparatus, shown in figure 2, has been described in reference 2. Load-deflection graphs were obtained in each test on a Southwark-Templin autographic recorder, which was operated by a Southwark-Peters plastics extensometer.

The 1- by 3-inch specimens, which were immersed in the various test fuels, were cut into two 1- by 1.5-inch specimens for the flexural tests. Because the test specimens were too short, a span-depth ratio of 8 to 1 was used instead of 16 to 1 as prescribed by reference 1. The reference surface of the specimen was on the tension side during the test. The radius of the support and pressure pieces was 1/32 inch. The relative rate of head motion was 0.01 inch per minute.

The flexural strength and the flexural modulus of elasticity were calculated in accordance with the equations given in Method No. 1031 of reference 1. The flexural-strength values reported are considered to be accurate to 1 percent and the flexural-modulus-of-elasticity values to 3 percent. All the values for the flexural properties are the averages obtained with four specimens except the initial values, which are the averages for six specimens.

The initial values for the flexural properties were determined on specimens which were heated in a circulating-air oven at 122° F for 48 hours and then conditioned for 48 hours at 77° F and 50-percent relative humidity prior to test. The changes in the flexural strength and the flexural modulus of elasticity as a result of immersion in the various fuels were calculated from these initial values.

Cyclic and Continuous Fuel-Immersion Tests

Each cycle of the cyclic fuel-immersion test consists of a 24-hour immersion and a 24-hour drying period. The specimens were immersed individually in 200 ml of test fuel in closed glass containers. Weight and dimensional measurements and flexural tests were made after 10 cycles of test and reconditioning at 77° F and 50-percent relative humidity for 48 hours.

The continuous fuel-immersion test consists of 7, 30, 90, 180, and 360 days of immersion. The specimens were immersed individually in 200 ml of test fuel in closed glass containers. Weight and dimensional measurements and flexural tests were made immediately after removing the specimens from the fuel on one set of specimens and after reconditioning for 7 days at 77° F and 50-percent relative humidity on a second set.

RESULTS AND DISCUSSION

Weight and Dimensional Changes

The changes in weight, length and width, and thickness of the laminates immersed in heptane, toluene, and SR-6 are shown in table II for cyclic fuel immersion, and in tables III to V and figures 3 to 5 for continuous fuel immersion. The samples having changes greater than ±1 percent for weight, ±0.1 percent for length and width, and ±0.5 percent for thickness in the cyclic fuel-immersion test and after 360 days of continuous fuel immersion are shown in table VI. The data for the low-pressure grade C phenolic laminate V were not included in the tables and in the discussion because of its great variability but are shown in figures 3 to 5.

Cyclic fuel-immersion test.- In the cyclic fuel-immersion test practically all of the weight changes of the samples for all the fuels as well as the majority of the dimensional changes for heptane and toluene are positive. In SR-6 nearly half of the changes in length and width, and over half of the changes in thickness are negative. The positive changes indicate that there is some retention of liquid accompanied by a slight swelling. Considering the magnitude of the changes for each sample in the three fuels regardless of sign, in the majority of cases the greatest changes in weight and length and width of the samples occurred in toluene, whereas in thickness the greatest changes were fairly well-distributed between toluene and SR-6. The greater positive changes obtained with toluene compared with those obtained with heptane may be partly ascribed to the greater volatility of heptane.

None of the samples showed weight changes in heptane of over 0.5 percent, and about one-half of them exhibited changes of 0.1 percent or less. In toluene the cotton-fabric unsaturated-polyester laminate N showed a change of 2.83 percent. The remainder of the laminates changed less than 1 percent, and about one-half of the samples showed changes of less than 0.5 percent. In SR-6 the laminate N showed a change of 1.54 percent. The remainder of the samples showed changes of less than 0.35 percent, and nearly half of the samples exhibited changes of 0.05 percent or less. The glass-fabric unsaturated-polyester laminate X had the smallest average change for the three fuels, with individual values of less than 0.1 percent.

The laminate N showed length and width changes of 0.11, 0.14, and 0.16 percent in heptane, toluene, and SR-6, respectively. The remainder of the samples exhibited changes of less than 0.1 percent.

The cotton-fabric unsaturated-polyester laminate N immersed in toluene and SR-6, and the low-pressure grade C phenolic L in SR-6, showed thickness changes of 2.3, 1.2, and 1.6 percent, respectively. The remainder of the samples changed less than 1 percent.

The laminate X exhibited the greatest stability and the laminate N the least.

Continuous fuel-immersion test.- In the continuous fuel-immersion test the majority of the changes in weight and dimensions were positive. The changes, regardless of sign, were equal to or higher for the "tested immediately" condition than for the "reconditioned 7 days" condition in the majority of cases. In the majority of cases immersion in toluene caused the greatest changes. The changes in weight and dimensions, in the majority of cases, attained their maximum values at the 180-day period. The reduction in the changes during the succeeding 180-day period indicates that the fuels may have dissolved some of the resin.

It is noted that for a given type of laminate the weight changes varied considerably among the samples. For example, samples J, I, and W are all grade C laminates made with the same phenolic resin. In most cases the changes for sample W for all three fuels are about double the corresponding values for sample J. Among the glass-fabric unsaturated-polyester laminates, samples E and AA exhibited changes higher than 1 percent in each of the three fuels during the course of the 360-day immersion tests; sample X at no time changed as much as 0.3 percent. The cotton-fabric unsaturated-polyester laminate H showed changes roughly one-tenth of those of sample N, a material absorbing greater than 5 percent of liquid in each of the fuels.

Similar behavior, namely, a wide spread in the changes for samples of a given type of laminate, is evident (table V) in the thickness changes of the unsaturated-polyester laminates.

A comparison of the changes in the various samples after 360-days' immersion in the fuels follows:

(1) Weight changes at 360 days. In heptane the cotton-fabric unsaturated-polyester laminate N and the glass-fabric unsaturated-polyester laminate AA in the "tested immediately" condition showed changes of 6.60 and 1.44 percent, respectively. The remainder of the samples exhibited changes of less than 1 percent, both when tested immediately and after 7 days' reconditioning. In toluene more than one-half of the samples when tested immediately and more than three-fourths of the materials in tests after reconditioning 7 days showed changes of less than 1 percent. In SR-6 the laminates N, E, and AA in the "tested immediately" condition and the laminate N in the condition after 7 days' reconditioning showed changes of 9.32, 1.30, 1.65, and 4.34 percent, respectively. The remainder of the samples had changes of less than 1 percent. The lignin paper laminate D, the grade C phenolic laminate J, and the glass-fabric unsaturated-polyester laminate X have the least average weight changes for all fuels and both test conditions after 360 days' immersion with no individual changes greater than 0.3 percent.

(2) Length and width changes at 360 days. The laminate N in heptane and SR-6, and the laminates F, H, K, and N in toluene showed changes greater than 0.1 percent. The remainder of the samples exhibited changes of 0.1 percent or less.

(3) Thickness changes after 360 days. The unsaturated-polyester laminates F, N, and X in heptane, E, F, N, Y, and AA in toluene, and N and AA in SR-6 showed changes greater than 0.6 percent in either test condition or both. The remainder of the samples had changes of 0.6 percent or less.

Changes in Flexural Properties

The changes in flexural strength and flexural modulus of elasticity of the laminates after immersion in heptane, toluene, and SR-6 are shown in table VII for cyclic fuel immersion and in tables VIII and IX and figures 6 and 7 for continuous fuel immersion. The laminates exhibiting losses greater than 10 percent for flexural strength and 5 percent for flexural modulus of elasticity in the cyclic fuel-immersion test and after 360 days of continuous fuel immersion are listed in table VI. The data for the low-pressure grade C phenolic laminate V were not included in the tables and in the discussion because of its great variability but are shown in figures 6 and 7.

Cyclic fuel-immersion test.- In the cyclic fuel-immersion test approximately two-thirds of the changes in flexural strength and in flexural modulus of elasticity are negative in each fuel. Considering the changes for each sample in the three fuels, it is noted that the losses are well-distributed among the three fuels. The grade AA phenolic laminate K exhibited the greatest positive changes in all three fuels in both flexural strength and flexural modulus of elasticity, although the initial values of these two properties for sample K are among the lowest.

Of the 18 samples tested in each fuel, only 4, none of which were cotton-fabric phenolics, had losses in flexural strength greater than 5 percent. Two samples, the glass-fabric unsaturated-polyester laminate E and the cotton-fabric unsaturated-polyester laminate N, had losses greater than 10 percent in each of the three fuels.

Approximately one-half of the materials exhibited losses in flexural modulus of elasticity of less than 5 percent in each fuel. Only the cotton-fabric unsaturated-polyester laminate H and the grade L phenolic laminate J had losses greater than 10 percent in each of the three fuels.

The samples which showed the greatest flexural stability in the three fuels were the cotton-fabric melamine laminate M, the cotton-fabric phenolic laminate L, the high-strength-paper phenolic laminate S, the cotton-fabric unsaturated-polyester laminate F, and the glass-fabric unsaturated-polyester laminate AB. The changes in both flexural strength and flexural modulus of elasticity did not exceed 5 percent. Samples X and K, which showed increases but no decreases greater than the preceding limits, were considered to have withstood the cyclic immersion test favorably. The cotton-fabric unsaturated-polyester laminate N exhibited the greatest changes.

Continuous fuel-immersion test.- In the prolonged fuel-immersion test most of the changes in flexural strength and flexural modulus of elasticity are negative. Eighty percent of the differences in the percentage values between the "tested immediately" and "reconditioned 7 days" conditions of test for the three fuels in flexural strength and flexural modulus of elasticity are 5 percent or less. It is considered that differences of this order are not significant. This indicates that in the majority of cases the deterioration occurred during the immersion and that retained solvent in the "tested immediately" condition had little effect on the strength and modulus of elasticity. Most of the differences for flexural strength and flexural modulus of elasticity were approximately the same for the three fuels in the two test conditions; where there were exceptions, the differences were usually greatest in toluene. Most of these large differences took place in the unsaturated-polyester laminates.

At no time during the continuous immersion test did any cotton-fabric phenolic laminate show losses in flexural strength exceeding 10 percent in the three fuels. This was also true of two glass-fabric unsaturated-polyester materials, X and AB, the paper phenolic laminate S, and the rayon phenolic laminate Z. The paper and cotton-fabric phenolic laminates exhibited the following trend with regard to the flexural modulus of elasticity in the course of the immersion tests: After 7 days' immersion the changes were losses, and as the test progressed the losses decreased with some samples showing gains at the end of the test. The changes for the cotton-fabric phenolic materials were about -10 to -20 percent at 7 days, and at 360 days the changes were about -5 to 5 percent.

It is noted that, just as in the cyclic immersion test, the various samples of polyester laminates varied considerably in their flexural-strength behavior on prolonged immersion.

A comparison of the changes in the flexural properties of the various samples after 360 days' immersion in the fuels follows:

(1) Flexural-strength changes at 360 days. In heptane only the unsaturated-polyester laminates E, N, and Y showed losses greater than 10 percent. In toluene the only samples that showed losses greater than 10 percent in either test condition were unsaturated-polyester laminates. Samples X and AB were the only materials of this type which did not exceed 10-percent loss. In SR-6 only the unsaturated-polyester laminates E, N, and Y showed losses greater than 10 percent. In each of the three fuels and for both test conditions, nearly half of the samples had losses greater than 5 percent. The grade AA phenolic laminate K was the only material that exhibited increases for both test conditions in each of the three fuels.

(2) Flexural-modulus-of-elasticity changes at 360 days. In heptane none of the samples exhibited losses greater than 5 percent for either

test condition. In toluene the unsaturated-polyester laminates X and Y showed losses of 1 percent or less in both test conditions. The remaining unsaturated-polyester laminates showed losses of 5 percent or more. In SR-6 the only samples that had losses greater than 5 percent in either test condition were the unsaturated-polyester laminates E, N, and AB and the lignin paper laminate D. The phenolic laminates K, L, and S and the melamine laminate M were the only samples that exhibited increases for both test conditions in all three fuels, and the phenolic laminate K had the largest increases.

The only sample which exhibited changes not exceeding 5 percent[1] in both flexural strength and modulus of elasticity after 360 days' immersion in each fuel was sample J. Other samples exhibiting satisfactory behavior were the asbestos-fabric phenolic laminate K, which exhibited positive changes, and the cotton-fabric phenolic laminates L and W, which showed no losses greater than 5 percent but whose increases were more than 5 percent in some instances. The cotton-fabric unsaturated-polyester resin laminate N showed the greatest losses in flexural properties.

SUMMARY OF RESULTS

The following statements summarize the actual numerical results obtained in this investigation of the effect of fuel immersion on laminated plastics. Since there may be appreciable differences in the properties of individual sheets taken from the same batch, in different batches made by the same manufacturer, and in similar laminates made by different manufacturers, any general inferences drawn from these data about a given type of laminate should be considered tentative.

1. No one sample exhibited smaller changes than all the other samples in all properties for all fuels and for both cyclic and continuous immersion.

2. In all three fuels the weight changes of the majority of the laminates were less than 1 percent in the cyclic test, and did not exceed 1.5 percent after continuous immersion of 360 days. The largest weight changes were usually obtained with the unsaturated-polyester laminates in toluene.

3. With very few exceptions, and those mainly cotton-fabric unsaturated-polyester samples, the length and width changes after either

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[1]Changes in the flexural properties of less than 5 percent are not considered significant because of the variability of the material.

the cyclic or the 360-day immersion in the fuels did not exceed 0.1 percent. In both types of test the changes in thickness were, in the majority of cases, less than 1 percent. The exceptions occurred mainly in the 360-day immersion test for several unsaturated-polyester laminates in toluene.

4. The best weight and dimensional stability in all three fuels in the cyclic test was observed with the glass-fabric unsaturated-polyester laminate X.

5. After the 360-day immersion test, the weight and dimensional changes were, in the majority of cases, higher for the samples when tested immediately as compared with measurements after reconditioning for 7 days.

6. The changes in flexural strength for the cyclic test and after the 360-day immersion test were, in the majority of cases, negative. However, the losses were less than 10 percent for samples except some unsaturated-polyester laminates. For the latter samples in the 360-day test greater losses usually occurred in toluene than in the other fuels.

7. The changes in flexural modulus of elasticity were, in the majority of cases, negative in the cyclic and the continuous immersion tests. In the cyclic test no losses greater than 10 percent were shown by the samples except one phenolic laminate and several unsaturated-polyester samples. After 360 days' immersion no losses greater than 10 percent occurred except for some unsaturated-polyester laminate samples in toluene or in SR-6 or in both.

8. The unsaturated-polyester laminate samples varied widely among themselves in regard to the magnitude of the change in a given property after the immersion tests.

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Washington, D. C., February 14, 1949

REFERENCES

1. Federal Spec. L-P-406a: Plastics, Organic; General Specifications, Test Methods; Govt. Printing Office, Jan. 24, 1944.

2. Axilrod, B. M., Thiebeau, R. W., and Brenner, G. E.: A Variable Span Flexure Test Jig for Plastics. Bull. No. 148, A.S.T.M. (Philadelphia), Oct. 1947, p. 96.

TABLE I.- DESCRIPTION OF MATERIALS

Laminate	Type of laminate	Manufacturer	Thickness (in.) (1)	Density (gram/cm³) (1)	Resin: Designation	Resin: Content (percent by weight)	Reinforcement: Type	Reinforcement: Thread count, Warp	Reinforcement: Thread count, Filling	Ply arrangement	Number of plies	Pressure (psi)	Molding conditions: Curing temperature, Initial (°F)	Molding conditions: Curing temperature, Maximum (°F)	Molding conditions: Time, Curing (min)	Molding conditions: Time, Cooling (min)
C	High-strength paper phenolic	Consolidated Water Power & Paper Co.	0.121	1.42	———	———	Paper	—	—	Cross	—	250	—	———	———	———
D	Lignin paper	Formica Insulation Co.	.126	1.38	Lignin	———	Lignin paper	—	—	———	—	—	—	———	———	———
E	Glass-fabric unsaturated polyester	Swedlow Aeroplastics Corp.	.134	1.69	Marco MR-1A	55-63	Glass fabric, plain weave	29	17	Cross	7	—	—	———	———	———
F	Muslin cotton-fabric unsaturated polyester	Swedlow Aeroplastics Corp.	.123	1.31	Marco MR-1A		Cotton fabric (muslin), twill weave	70	68		7	—	—	———	———	———
H	Enameled-duck cotton-fabric unsaturated polyester	Pittsburgh Plate Glass Co., Columbia Chemical Division	.147	1.36	Allymer CR 39	62-65	Cotton fabric (enameled duck), plain weave, 8 oz/yd²	36	32	Cross	6	1-5	158	239	120 at 158° F 600 at 158°-239° F	Gradual
I	Grade C phenolic	Synthane Corp.	.124	1.35	Bakelite BV-1112	48	Cotton fabric, plain weave, 10 oz/yd²	50	40	Cross	7	1000	—	340	50	20
J	Grade L phenolic	Synthane Corp.	.124	1.34	Bakelite BV-1112	48-52	Cotton fabric, plain weave, 3.7 oz/yd²	80	80	Parallel	19	1620	—	320	45	25
K	Grade AA phenolic	Synthane Corp.	.148	1.49	Bakelite No. 2417	47	Asbestos fabric, plain weave, 18 oz/yd²	18	16	Parallel	5	1000	—	340	50	20
L	Enameled-duck cotton-fabric phenolic	Bakelite Corp.	.152	1.36	Bakelite BV-16887	52	Cotton fabric (enameled duck), plain weave, 8 oz/yd²	84	28	Cross	9	250	—	325	30	———
M	Canvas cotton-fabric melamine	Formica Insulation Co.	.145	1.47		50-55	Cotton fabric (canvas), plain weave, 8 oz/yd²	90	28	Parallel	11	1400	—	284-288	———	———
N	Canvas cotton-fabric unsaturated polyester	Formica Insulation Co.	.150	1.13	Laminac	50-55	Cotton fabric (canvas), plain weave, 8 oz/yd²	90	28	Parallel	7	15	—	230-248	———	———
S	High-strength-paper phenolic	Consolidated Water Power & Paper Co.	.122	1.42	Bakelite No. 16526	30	High-strength Mitscherlich paper	—	—	Cross	54	250	—	310 ± 10	12	Gradual
V	Low-pressure grade C phenolic	Synthane Corp.	.150	1.26	Bakelite BV-16887	51	Cotton fabric (Army duck), plain weave, 10 oz/yd²	50	40	Cross	7	100	—	320	50	———
W	High-pressure grade C phenolic	Synthane Corp.	.138	1.36	Bakelite BV-1112	47	Cotton fabric (Army duck), plain weave, 10 oz/yd²	50	40	Cross	7	1000	—	320	50	———
X	Glass-fabric unsaturated polyester	Pittsburgh Plate Glass Co., Columbia Chemical Division	.125	1.64	Allymer CR 149	50-55	Glass fabric (ECC-11-162), plain weave, 12 oz/yd²	28	16	Cross	6	1-5	176	207	1080 at 176° F 60 at 207° F	Gradual
Y	Glass-fabric unsaturated polyester	Pittsburgh Plate Glass Co., Columbia Chemical Division	.114	1.66	Allymer CR 39	48-50	Glass fabric (ECC-11-162), plain weave, 12 oz/yd²	28	16	Cross	6	1-5	176	207	900 at 176° F 60 at 207° F	Gradual
Z	Rayon-fabric phenolic	Formica Insulation Co.	.160	1.35	Iron-sides 91-L	37-40	Rayon fabric (Celanese Corp., WE-3975, high-tenacity Fortisan rayon-warp thread, cotton filling thread, twill weave, 12.5 oz/yd²)	75	12	Cross	6	1100	—	320	20 over 302° F	20
AA	Glass-fabric unsaturated polyester	Marco Chemicals, Inc.	.118	1.69	Marco MR-17B	45.5	Glass fabric (ECC-11-162), plain weave	29	17	Parallel	7	None	140	240	60 at 140° F 60 at 240° F	———
AB	Glass-fabric unsaturated polyester	Army Air Forces, Air Technical Service Command	.130	1.84	Plaskon 900	43	Glass fabric (ECC-112), heat-treated, plain weave	40	40	Parallel	45	40	180	220	120 at 180° F 120 at 220° F	———

[1]Average for all specimens tested.

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TABLE II.- CHANGES IN WEIGHT AND DIMENSIONS OF LAMINATED PLASTICS AFTER CYCLIC FUEL-IMMERSION TEST

[Each cycle of test consists of a 24-hr immersion and a 24-hr drying period. Weight and dimensional measurements were made after 10 cycles of testing and reconditioning at 77° F and 50-percent relative humidity for 48 hr. Each value is based on average for two specimens.]

Laminate	Change (percent) in weight after immersion in -			Average of length and width change (percent) after immersion in -			Change (percent) in thickness after immersion in -		
	Heptane	Toluene	SR-6	Heptane	Toluene	SR-6	Heptane	Toluene	SR-6
Lignin paper									
D	0.08	0.52	0.06	0.02	0.05	0	0.3	0.2	-0.1
Phenolic; high-strength paper									
C	0.09	0.42	0.01	0	0.01	-0.01	0.1	0	-0.1
S	.10	.35	.04	.02	.04	-.04	.2	.2	.1
Phenolic; cotton fabric									
J (grade L)	0.07	0.42	0.01	0.02	0.05	-0.01	-0.1	0.1	-0.1
I (grade C)	.10	.56	.02	.01	.05	-.02	.2	0	-.8
W (grade O)	.14	.85	.05	.04	.07	.02	.1	0	-.3
L (grade C; low pressure)	.26	.88	.14	.03	.09	-.03	.5	.1	1.6
Phenolic; rayon fabric									
Z	0.34	0.33	0.32	0.04	0.05	0.04	0	0.2	0
Phenolic; asbestos fabric									
K	0.16	0.83	0.20	0.02	0.05	0.03	0	0.2	0.5
Melamine; cotton fabric									
M	0.16	0.65	-0.03	0.03	0.08	-0.03	0.1	0.4	-0.2
Unsaturated polyester; cotton fabric									
F	0.09	0.54	0	0.02	0.08	-0.03	0	0.3	-0.4
H	.19	.60	.04	.04	.09	.01	.1	.2	-.1
N	.49	2.83	1.54	.11	.14	.16	.4	2.3	1.2
Unsaturated polyester; glass fabric									
E	0.09	0.30	0.14	0	-0.02	0	0	0.5	-0.4
X	.08	.08	.08	.01	.01	.01	0	-.1	-.1
Y	.12	.20	.16	.01	.01	.01	.1	.3	-.4
AA	0	.29	.06	0	0	.01	.7	.6	.2
AB	.17	.21	.19	.03	.01	.03	.2	0	.1

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TABLE III.- CHANGES IN WEIGHT OF LAMINATED PLASTICS AFTER CONTINUOUS IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

[Each value is based on average for two specimens]

Laminate	When tested (1)	Change (percent) after immersion in heptane for -					Change (percent) after immersion in toluene for -					Change (percent) after immersion in SR-6 for -				
		7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days
Lignin paper																
D	i	0.12	0.24	0.05	0.58	0.10	0.28	0.29	0.06	0.66	0.02	0.11	0.16	-0.16	0.68	-0.10
	r	.22	.34	.06	.56	.11	.18	.32	-.02	.66	.00	.16	.22	-.12	.63	-.12
Phenolic; high-strength paper																
C	i	0.07	0.20	0.12	0.52	0.30	0.05	0.24	0.08	1.18	0.22	0.05	0.14	-0.04	0.63	0.06
	r	.18	.30	.16	.52	.32	.15	.33	.07	.62	.18	.22	.20	-.08	.56	.08
S	i	.05	.18	.08	.47	.18	.08	.20	.09	.56	.14	.06	.14	-.06	.56	0
	r	.16	.25	.08	.46	.80	.14	.27	.04	.55	.20	.14	.19	-.04	.54	.06
Phenolic; cotton fabric																
J (grade L)	i	0.13	0.26	0.16	0.54	0.18	0.13	0.34	0.13	0.82	0.30	0.12	0.22	-0.03	0.70	0.04
	r	.16	.31	.07	.45	.12	.15	.30	.06	.66	.18	.16	.21	-.07	.57	.04
I (grade C)	i	.78	.83	.14	.86	.28	.27	.66	.14	1.14	.33	.15	.45	-.06	1.76	.08
	r	.26	.42	.08	.69	.16	.22	.37	.06	1.00	.19	.28	.32	-.10	.80	0
W (grade C)	i	.35	.63	.36	1.12	.42	.56	.61	.32	1.63	.40	.24	.62	.12	1.26	.24
	r	.37	.46	.08	.80	.11	.36	.53	.10	.92	.18	.29	.38	.05	.94	.04
L (grade C; low pressure)	i	.84	.97	.78	1.52	.76	1.00	1.18	.86	1.82	.91	.90	.94	.57	1.66	.70
	r	.28	.38	.25	.68	-.04	.28	.40	.02	1.48	.12	.32	.26	-.09	.71	-.04
Phenolic; rayon fabric																
Z	i	0.19	0.33	0.26	0.72	0.43	0.24	0.40	0.25	1.02	0.54	0.23	0.26	0.10	0.46	0.53
	r	.11	.15	-.04	.44	.15	.09	.18	-.04	.64	.18	.10	.10	-.10	.58	.18
Phenolic; asbestos fabric																
K	i	0.62	1.35	0.94	1.15	0.74	1.57	1.38	1.64	1.70	1.48	1.09	0.86	0.73	1.57	0.94
	r	.18	.24	.06	.45	.17	.24	.52	.41	1.28	.96	.22	.27	.12	.62	.56
Melamine; cotton fabric																
M	i	0.34	0.55	0.28	0.82	0.35	0.56	0.66	0.42	1.04	0.58	0.45	0.51	0.36	1.12	0.98
	r	.05	.20	-.10	.36	.02	.13	.29	0	.50	.12	.21	.14	.02	.44	-.50
Unsaturated polyester; cotton fabric																
F	i	0.09	0.24	-0.04	0.48	-0.23	0.66	1.32	1.14	1.19	4.35	0.12	0.18	-0.08	0.71	-0.03
	r	.16	.21	-.04	.42	.16	.20	.55	.52	.90	2.72	.12	.12	-.11	.55	-.04
H	i	.14	.28	.13	.80	.18	.26	.50	.37	1.77	1.05	.18	.27	.03	1.18	.54
	r	.20	.26	.04	.60	.08	.30	.44	.38	1.38	.74	.16	.24	0	.93	.36
N	i	1.85	4.06	4.28	5.24	6.60	7.01	9.48	10.82	14.46	14.22	4.34	6.55	8.26	8.84	9.32
	r	.20	.49	.30	.85	.52	1.60	3.42	4.77	5.66	5.59	1.26	1.58	1.40	4.72	4.34
Unsaturated polyester; glass fabric																
E	i	0.11	0.22	0.28	1.16	0.34	0.46	2.39	3.73	6.80	4.98	0.25	0.44	0.52	2.31	1.30
	r	.06	.12	.12	.20	.21	.36	1.00	1.62	2.24	1.70	.12	.20	.30	.63	.79
X	i	.06	.08	.07	.16	.11	.09	.12	.08	.24	.11	.04	.08	.02	.20	.10
	r	.04	.06	.04	.14	.11	.03	.08	.04	.19	.11	.03	.05	0	.15	.08
Y	i	.17	.38	.18	.32	.22	.32	.54	.77	1.44	1.24	.23	.32	.32	.54	.51
	r	.02	.03	-.04	.14	-.01	.08	.24	.52	.85	1.06	.06	.05	.02	.31	.34
AA	i	1.20	1.95	.35	1.96	1.44	1.26	2.80	3.21	4.30	3.56	.95	1.18	1.86	2.92	1.65
	r	-.14	-.15	-.16	-.04	-.21	.08	.26	.58	1.17	.96	-.20	-.06	-.10	.18	.72
AB	i	.13	.22	.26	.52	.60	.18	.28	.34	.59	.78	.12	.22	.26	.50	.16
	r	.07	.11	.02	.20	.06	.08	.14	.04	.34	.16	.07	.10	0	.27	.09

[1] i, tested immediately; r, tested after reconditioning for 7 days at 77° F and 50-percent relative humidity.

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TABLE IV.- CHANGES IN LENGTH AND WIDTH OF LAMINATED PLASTICS AFTER CONTINUOUS IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

[Each value is based on average for two specimens]

Laminate	When tested (1)	Change (percent) after immersion in heptane for -					Change (percent) after immersion in toluene for -					Change (percent) after immersion in SR-6 for -				
		7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days
Lignin paper																
D	i	-0.03	0.04	0.01	0.11	0.03	0.01	0.03	-0.01	0.08	0.04	0.01	0.01	-0.01	0.09	0.01
	r	.03	.05	01	.09	.02	.03	.06	-.02	.10	.02	.01	.02	.01	.09	-.01
Phenolic; high-strength paper																
C	i	0	0.01	0.01	0.06	0.03	0.01	0	0	0.05	0.02	0.01	0.02	0.01	0.05	0.01
	r	.02	.01	0	.08	.06	.02	.03	.01	.06	.04	.01	.01	-.03	.07	.03
S	i	0	-.01	-.02	.02	.05	.02	.01	.02	.06	.04	.03	0	0	.05	.02
	r	0	.01	.01	.06	.03	.02	.01	.02	.05	0	.01	0	.02	.04	.02
Phenolic; cotton fabric																
J (grade L)	i	-0.01	0.01	0	0.10	0.03	0.01	0.04	0.01	0.11	0.06	0	-0.01	-0.01	0.07	0.03
	r	.02	.04	.02	.12	.04	.02	.05	-.01	.12	.06	0	.01	0	.09	.03
I (grade C)	i	-.01	.04	.02	.12	.05	.02	.03	-.04	.12	.02	.01	.01	-.02	.12	.01
	r	.03	.03	0	.09	.03	.04	.04	-.01	.13	.03	.01	.02	.04	.13	0
W (grade C)	i	-.01	.02	.01	.11	.04	0	.03	.01	.13	.04	.02	.01	-.02	.12	.01
	r	.02	.04	-.03	.11	.04	.03	.05	.01	.11	.02	.05	.04	-.03	.09	.01
L (grade C; low pressure)	i	0	.03	0	.11	.01	.01	.02	-.02	.13	.03	0	-.01	-.02	.12	.02
	r	.04	.03	-.01	.11	.04	.04	.05	-.04	.10	.02	.01	-.01	-.02	.08	-.01
Phenolic; rayon fabric																
Z	i	-0.02	0.01	-0.01	0.07	0.05	0.01	0	0	0.08	0.04	0	0.03	-0.03	0.07	0.02
	r	.02	.02	-.01	.07	.04	.03	.02	0	.08	.03	.03	0	.02	.07	.04
Phenolic; asbestos fabric																
K	i	-0.01	0.01	0.03	0.08	0.05	0.10	0.03	0.06	0.18	0.14	0.04	0	0.02	0.11	0.07
	r	.02	0	-.01	.06	.03	.04	.07	.03	.16	.14	.02	.01	.04	.10	.10
Melamine; cotton fabric																
M	i	0.02	0.01	-0.02	0.09	0.03	0.03	0.03	0	0.11	0.07	0.01	-0.02	0	0.12	0.01
	r	.01	.02	-.03	.08	.02	.02	.05	-.01	.11	.04	.05	-.01	-.01	.08	.01
Unsaturated polyester; cotton fabric																
F	i	0	0.06	-0.01	0.07	0.01	0	0.08	0.07	0.15	0.27	0	0.03	0	0.13	-0.02
	r	.01	.06	.01	.09	0	.01	.04	.04	.13	.15	0	.02	-.01	.11	.02
H	i	0	.01	.01	.16	.05	.02	.05	.04	.29	.17	.03	.03	.02	.18	.09
	r	.04	.04	-.02	.11	.04	.06	.07	.02	.24	.13	.02	.01	.02	.16	.07
N	i	.09	.08	.13	.23	.25	.37	.55	.63	.85	.86	.23	.34	.36	.58	.56
	r	.04	.08	.07	.15	.26	.02	.26	.41	.62	.53	.10	.15	.23	.44	.42
Unsaturated polyester; glass fabric																
E	i	0.03	0.04	0.02	0.06	0.04	0.03	0.09	0.08	0.09	0.10	-0.01	-0.02	0.03	0.05	0.04
	r	0	.02	.01	.04	.03	.02	-.02	-.03	-.02	-.02	0	-.01	.02	.06	.03
X	i	-.01	.03	-.01	.02	.01	.01	.04	-.01	.06	.05	-.01	-.02	0	.04	.04
	r	-.01	.01	.01	.04	.08	-.01	0	.02	.04	.05	.02	-.02	.01	.03	.05
Y	i	-.01	-.02	0	.04	.03	-.01	0	.02	.05	.06	.01	0	-.01	.02	.05
	r	0	0	0	.02	.02	-.02	0	.02	.05	.05	.01	.01	.04	.03	.02
AA	i	-.02	-.01	-.01	.03	.01	.05	-.01	.02	.03	.07	.03	.01	0	.03	.08
	r	-.03	.01	0	.01	.02	-.02	-.03	0	.04	.02	.01	-.03	.03	.04	-.02
AB	i	.01	.01	0	.05	.04	0	.04	.01	-.01	.04	.03	.01	-.01	.05	.02
	r	.02	.01	-.01	.06	.03	-.03	0	-.02	.04	.03	.02	.02	0	.06	.01

[1] i, tested immediately; r, tested after reconditioning for 7 days at 77° F and 50-percent relative humidity.

TABLE V.- CHANGES IN THICKNESS OF LAMINATED PLASTICS AFTER CONTINUOUS IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

[Each value is based on average for two specimens]

Laminate	When tested (1)	Change (percent) after immersion in heptane for -					Change (percent) after immersion in toluene for -					Change (percent) after immersion in SR-6 for -				
		7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days
Lignin paper																
D	i	-0.1	0.1	0	0.3	0	0	0	-0.2	0.3	-0.1	0	0.1	-0.1	0.3	-0.2
	r	.1	.2	.2	.2	.1	.1	.2	0	.4	-.1	.1	.2	-.1	.4	-.2
Phenolic; high-strength paper																
C	i	-0.2	0.1	0.2	0.5	0.3	0	0.3	0.1	0.4	0.2	0.2	0.1	0	0.5	0
	r	-.4	.1	.2	.2	.3	.1	.4	.2	.5	.2	.3	.3	-.1	.4	.1
S	i	-.1	.1	.1	.4	.2	.1	.2	.1	.2	.1	0	0	.1	.4	0
	r	.1	.2	.1	.3	.5	.2	.1	.1	.3	.2	.1	.1	0	.3	.1
Phenolic; cotton fabric																
J (grade L)	i	-0.2	0.1	0.1	0.1	0	0.1	0	0.3	0.2	0	0.2	0.2	-0.2	0.2	-0.1
	r	0	.2	0	.1	.1	.1	.2	.2	.3	.2	0	0	-.2	.1	0
I (grade C)	i	-.1	.2	.1	.2	0	-.1	.2	-.2	0	0	.1	.1	0	.3	-.1
	r	.1	.1	0	.2	0	0	.2	0	.2	0	.1	0	-.1	.2	-.2
W (grade C)	i	0	0	0	.1	-.1	0	.2	0	.1	.2	0	.1	-.1	.3	0
	r	0	.2	.1	.1	0	.1	.2	0	.1	-.1	.1	0	-.1	.3	-.3
L (grade C; low pressure)	i	0	.1	0	.2	0	-.1	.1	0	.2	-.1	.1	.1	0	.2	-.1
	r	0	.1	.1	0	-.1	0	.1	.1	.2	-.1	0	.1	-.1	.2	-.1
Phenolic; rayon fabric																
Z	i	-0.1	0	0.1	0.4	0.3	0	0.3	0.2	0.3	0.3	0	-0.1	0.1	0.2	0.1
	r	0	.2	.1	.2	.3	.2	.1	-.1	.4	.2	.1	.1	.1	.2	.2
Phenolic; asbestos fabric																
K	i	0	0	0.1	0.1	0.1	0.2	0.2	0.4	0.3	0.4	0.1	0.2	0.1	0.2	0.1
	r	0	0	.1	.2	-.1	.1	.4	.1	.5	.3	.2	.2	-.1	.1	.2
Melamine; cotton fabric																
M	i	-0.1	0.1	0	0.1	-0.1	0	0.2	0	0.3	0	-0.1	0.1	-0.1	0.2	0.6
	r	0	0	0	.2	0	.1	.1	0	.2	-.1	0	0	0	.2	-.6
Unsaturated polyester; cotton fabric																
F	i	-0.2	0.1	0	0.3	-0.7	0.6	1.3	1.2	0.6	4.8	0.1	0.1	-0.1	0.3	-0.3
	r	.1	0	0	0.1	.2	.2	.3	.4	.4	2.8	.1	.2	0	.2	-.4
H	i	0	.2	-.2	0	-.1	0	.2	.1	.5	.1	.2	.1	.1	.3	.1
	r	0	.1	-.1	0	.1	-.5	.2	0	.4	0	.1	.1	-.2	.3	0
N	i	1.0	.7	.7	.7	.8	3.6	4.8	8.0	7.1	7.9	1.5	3.2	3.7	4.2	3.6
	r	-.1	.7	0	.7	.3	1.5	3.2	5.0	5.7	4.6	.7	1.7	2.4	3.8	3.1
Unsaturated polyester; glass fabric																
E	i	-0.1	0.2	0.1	-0.1	0	0.1	1.9	4.4	7.9	7.4	0	0.1	0	0.5	0.4
	r	-.1	.2	.1	.1	.1	-.1	1.2	3.0	4.9	4.5	.2	.2	0	.2	.3
X	i	-.1	0	.2	0	1.0	0	.1	.1	.6	.3	-.2	.1	0	.1	-.1
	r	-.2	.2	.4	.8	.1	-.2	0	.1	.5	.2	0	-.1	0	0	-.1
Y	i	.1	0	-.1	.3	0	1.0	.2	.6	1.2	1.0	0	.3	.1	.3	.1
	r	.2	0	0	.4	-.1	.1	.8	.1	.7	.8	-.3	.2	0	.2	.2
AA	i	.1	0	.1	.2	.1	1.2	1.9	2.2	2.7	2.7	.2	.4	.6	.9	.2
	r	.1	0	0	-.1	0	.3	.7	1.3	2.3	1.9	-.2	.3	.3	.6	1.5
AB	i	0	.1	0	-.1	0	0	.1	.1	.3	.1	-.1	.1	.1	.2	0
	r	0	.2	0	.1	-.6	.2	.2	-.1	.2	0	-.2	.2	0	0	-.2

[1] i, tested immediately; r, tested after reconditioning for 7 days at 77° F and 50-percent relative humidity.

TABLE VI.- LAMINATED PLASTICS WITH CHANGES IN PROPERTIES GREATER THAN SELECTED VALUES AFTER IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

[Letters are designations for laminates tested as shown in table I. Because of its variability, the phenolic laminate V was not included in this summary.]

Test condition	Heptane	Toluene	SR-6
Weight (> ±1-percent change)			
Cyclic immersion		N	N
Continuous immersion, 360 days			
Tested immediately	N,AA	E,F,H,K,N,Y,AA	E,N,AA
Reconditioned		E,F,N,Y	N
Length and width (> ±0.1-percent change)			
Cyclic immersion	N	N	N
Continuous immersion, 360 days			
Tested immediately	N	F,H,K,N	N
Reconditioned	N	F,H,K,N	N
Thickness (> ±0.5-percent change)			
Cyclic immersion	AA	N,AA	I,L,M
Continuous immersion, 360 days			
Tested immediately	F,N,X	E,F,N,Y,AA	M,N
Reconditioned	AB	E,F,N,Y,AA	M,N,AA
Flexural strength (> -10-percent change)			
Cyclic immersion	E,N	E,N	E,N
Continuous immersion, 360 days			
Tested immediately	E,N,Y	E,F,N,Y,AA	E,N,Y
Reconditioned	E,N	E,F,H,N,Y	E,N,Y
Flexural modulus of elasticity (> -5-percent change)			
Cyclic immersion	C,D,E,H,I,J,N,Z,AA	E,H,J,N,W,Z,AA	H,I,J,N,W,Z,AA
Continuous immersion, 360 days			
Tested immediately		E,F,H,N,AA,AB	E,N,AB
Reconditioned		E,F,H,N,AA	D,E,N

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TABLE VII.- CHANGES IN FLEXURAL PROPERTIES OF LAMINATED PLASTICS

AFTER CYCLIC FUEL-IMMERSION TEST

[Each cycle of test consists of a 24-hr immersion and a 24-hr drying period. Flexural tests were made after 10 cycles of test and reconditioning at 77° F and 50-percent relative humidity for 48 hr.]

Laminate	Initial flexural strength (psi) (1)	Change (percent) in flexural strength in - (2)			Initial flexural modulus of elasticity (psi) (1)	Change (percent) in flexural modulus of elasticity in - (2)		
		Heptane	Toluene	SR-6		Heptane	Toluene	SR-6
Lignin paper								
D	23.5 ± 0.4 × 10³	-7	-8	-3	1.92 ± 0.05 × 10⁶	-10	-5	-4
Phenolic; high-strength paper								
C	35.1 ± 0.4 × 10³	-4	-7	-9	2.57 ± 0.03 × 10⁶	-8	-5	-4
S	33.7 ± 0.3	-2	-2	-1	2.47 ± 0.01	-4	-5	-1
Phenolic; cotton fabric								
J (grade L)	17.4 ± 0.2 × 10³	3	3	1	1.12 ± 0.04 × 10⁶	-13	-11	-12
I (grade C)	22.9 ± 0.3	-2	-2	-1	1.24 ± 0.02	-8	-3	-6
W (grade C)	20.7 ± 0.2	8	3	-1	1.20 ± 0.04	0	-10	-7
L (grade C; low pressure)	20.7 ± 0.1	5	2	2	1.02 ± 0.03	-4	2	1
Phenolic; rayon fabric								
Z	46.4 ± 0.5 × 10³	-2	-3	-4	2.22 ± 0.04 × 10⁶	-9	-9	-7
Phenolic; asbestos fabric								
K	9.0 ± 0.1 × 10³	19	9	11	0.99 ± 0.06 × 10⁶	5	10	10
Melamine; cotton fabric								
M	25.4 ± 0.6 × 10³	-2	-3	0	1.62 ± 0.02 × 10⁶	-3	2	1
Unsaturated polyester; cotton fabric								
F	16.1 ± 0.4 × 10³	-4	-3	-4	0.71 ± 0.02 × 10⁶	-2	-1	2
H	13.1 ± 0.1	-4	-3	-6	.67 ± 0.02	-14	-12	-12
N	12.1 ± 0.2	-12	-19	-20	.45 ± 0.01	-8	-22	-16
Unsaturated polyester; glass fabric								
E	34.1 ± 0.1 × 10³	-13	-16	-14	1.81 ± 0.04 × 10⁶	-9	-17	1
X	41.2 ± 0.3	2	5	5	1.68 ± 0.01	4	6	9
Y	34.5 ± 0.2	-6	-5	-4	1.44 ± 0.02	2	1	0
AA	20.3 ± 0.9	11	0	4	1.82 ± 0.05	-6	-10	-8
AB	56.5 ± 0.9	-3	3	1	2.86 ± 0.02	0	-3	1

[1]Each value is average for six specimens. Accompanying plus or minus value is standard error.

[2]Each value is based on average for four specimens.

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TABLE VIII.- CHANGES IN FLEXURAL STRENGTH OF LAMINATED PLASTICS AFTER CONTINUOUS IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

Laminate	Initial flexural strength (psi) (1)	When tested (2)	Change (percent) after immersion in heptane for - (3)					Change (percent) after immersion in toluene for - (3)					Change (percent) after immersion in SR-6 for - (3)				
			7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days
Lignin paper																	
D	23.5 ± 0.4 × 10^3	i	-3	-6	-4	-6	-3	-6	-5	-7	3	0	-13	-6	-6	-5	-6
		r	-8	-9	-7	-3	-3	0	-6	-4	-3	-2	-6	-1	-2	-5	-6
Phenolic; high-strength paper																	
C	35.1 ± 0.4 × 10^3	i	-5	-6	-9	-17	-9	-5	-7	-7	-9	-5	-5	-8	-6	-11	-9
		r	-9	-1	-5	-7	-7	-4	-3	-9	-10	-9	-13	0	-7	-10	-9
S	33.7 ± 0.3	i	-4	-9	-3	-2	-2	0	3	-6	-3	-3	-5	0	-3	-4	-3
		r	-7	-6	-6	-1	-2	-2	-6	-5	-3	-3	-3	-3	-3	-4	-7
Phenolic; cotton fabric																	
J (grade L)	17.4 ± 0.2 × 10^3	i	-1	1	-1	-1	-1	1	3	2	0	-2	2	5	-6	3	2
		r	1	0	-1	-5	-1	1	0	1	1	-1	-1	3	0	-3	1
I (grade C)	22.9 ± 0.3	i	-10	-9	-2	-4	-5	-3	-3	-6	-5	-4	-2	-3	-7	-7	-6
		r	-5	-3	-1	-7	-5	0	-2	-6	-3	-6	-2	-5	-5	-8	-7
W (grade C)	20.7 ± 0.2	i	-4	-1	-7	-1	-4	-3	-4	-2	-2	1	-1	1	-6	-5	-1
		r	-2	2	-3	0	-1	-3	7	-3	-1	-4	1	3	-2	-3	-5
L (grade C; low pressure)	20.7 ± 0.1	i	-2	-2	-1	3	2	-1	3	1	2	1	-4	3	0	-1	-1
		r	-7	-1	10	1	1	-5	-2	1	1	1	-3	1	17	1	-1
Phenolic; rayon fabric																	
Z	46.4 ± 0.5 × 10^3	i	-6	-4	-6	-3	-4	-8	-5	-6	-5	-5	-3	-3	-3	-6	-7
		r	-4	-2	-4	-2	-4	-2	-3	-5	-4	-4	0	0	-5	-5	-7
Phenolic; asbestos fabric																	
K	9.0 ± 0.1 × 10^3	i	11	11	4	13	13	13	21	18	20	18	6	19	15	12	11
		r	11	8	17	20	10	13	11	14	9	21	6	11	10	13	9
Melamine; cotton fabric																	
M	25.4 ± 0.6 × 10^3	i	-4	-5	-6	-2	-7	-3	-4	-7	-6	-4	-6	-7	-5	-4	-7
		r	-7	-5	-8	-4	-6	-2	-5	-11	-4	-6	-6	-8	-3	-5	-1
Unsaturated polyester; cotton fabric																	
F	16.1 ± 0.4 × 10^3	i	-3	-6	-4	1	-4	-6	-11	-13	-5	-30	-1	-1	-1	-9	-3
		r	-6	-7	-4	-2	-5	-2	-2	-11	-5	-20	-15	-9	-11	-7	-2
H	13.1 ± 0.1	i	-3	-6	-3	-2	-6	-5	0	-9	-7	-8	-5	-3	-7	-11	-8
		r	-4	-5	-8	-4	-9	-1	-2	-5	-6	-11	-5	-1	-5	-7	-8
N	12.1 ± 0.2	i	-19	-29	-19	-9	-17	-44	-37	-34	-41	-46	-32	-40	-37	-36	-31
		r	-17	-21	-17	-7	-16	-34	-28	-30	-34	-30	-22	-30	-21	-29	-28
Unsaturated polyester; glass fabric																	
E	34.1 ± 0.1 × 10^3	i	-12	-13	-21	-28	-14	-15	-32	-46	-53	-50	-16	-15	-24	-27	-24
		r	-12	-12	-14	-22	-14	-11	-24	-36	-41	-38	-13	-12	-22	-20	-25
X	41.2 ± 0.3	i	4	5	-2	-2	-4	5	4	-2	-6	-3	7	7	-1	-7	-10
		r	7	6	-5	-4	-3	7	4	-1	-5	-2	7	8	-6	-6	-5
Y	34.5 ± 0.2	i	-11	-10	-14	-9	-13	-11	-13	-16	-21	-20	-11	-11	-15	-15	-18
		r	-11	-8	-11	-8	-10	-3	-9	-17	-16	-20	-7	-7	-14	-11	-16
AA	20.3 ± 0.9	i	-2	-3	-3	4	-2	-5	-13	-16	-20	-18	1	8	-3	-7	-2
		r	5	9	5	5	2	-6	-3	-6	-7	-10	3	7	-4	-3	-1
AB	56.5 ± 0.9	i	-4	1	-8	-5	-9	-5	-1	-7	-7	-7	-3	0	-8	-6	-9
		r	-5	1	-3	-2	-10	-5	-2	-10	-7	-10	-2	-1	-8	1	-9

[1]Each value is average for six specimens. Accompanying plus or minus value is standard error.

[2]i, tested immediately; r, tested after reconditioning for 7 days at 77° F and 50-percent relative humidity.

[3]Each value is based on average for four specimens.

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TABLE IX.- CHANGES IN FLEXURAL MODULUS OF ELASTICITY OF LAMINATED PLASTICS AFTER CONTINUOUS IMMERSION IN HEPTANE, TOLUENE, AND SR-6 FUEL BLEND

Laminate	Initial flexural modulus of elasticity (psi) (1)	When tested (2)	Change (percent) after immersion in heptane for - (3)					Change (percent) after immersion in toluene for - (3)					Change (percent) after immersion in SR-6 for - (3)				
			7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days	7 days	30 days	90 days	180 days	360 days
Lignin paper																	
D	$1.92 \pm 0.05 \times 10^6$	i	-8	-10	-11	0	-1	-10	-11	0	14	4	-13	-3	1	0	-1
		r	-11	-9	-2	-6	3	-12	-4	-2	6	3	-10	9	-5	-2	-10
Phenolic; high-strength paper																	
C	$2.57 \pm 0.03 \times 10^6$	i	-8	-11	-10	-14	3	-5	-11	-5	3	4	-8	-8	-2	2	0
		r	-9	-10	-4	-1	2	-9	-8	0	-2	-1	-10	7	-5	0	-3
S	2.47 ± 0.01	i	-8	-3	0	6	6	-6	2	-1	-1	9	-5	6	-1	9	6
		r	-8	-10	-4	1	8	-6	-8	0	-1	4	-7	0	-1	3	5
Phenolic; cotton fabric																	
J (grade L)	$1.12 \pm 0.04 \times 10^6$	i	-20	-14	-9	-5	-2	-16	-14	-4	1	0	-16	-16	-3	-1	3
		r	-15	-16	-6	5	1	-13	-14	-2	-6	2	-18	-10	-2	5	-1
I (grade C)	1.24 ± 0.02	i	-22	-17	2	2	0	-13	-9	-6	-4	-1	-10	-11	-2	-5	2
		r	-14	-8	1	-6	0	-10	-6	0	0	2	-16	1	0	-10	3
W (grade C)	1.20 ± 0.04	i	-15	-8	-2	-11	-2	-17	-19	-3	-15	0	-12	7	-5	-2	-4
		r	-15	-11	-9	-9	-2	-16	-1	-3	-6	-5	-16	-8	-9	-4	6
L (grade C; low pressure)	1.02 ± 0.03	i	-5	-4	8	-5	4	-3	-4	3	8	6	-4	-3	7	5	4
		r	-7	-5	1	7	0	-10	-3	4	1	7	-7	4	5	6	4
Phenolic; rayon fabric																	
Z	$2.22 \pm 0.04 \times 10^6$	i	-14	-13	-11	-8	-4	-13	-13	-7	-8	-2	-13	-10	-2	-4	-4
		r	-17	-15	-12	-8	-3	-15	-9	-9	-3	-5	-15	-7	-11	-5	-5
Phenolic; asbestos fabric																	
K	$0.99 \pm 0.06 \times 10^6$	i	7	8	-4	15	22	-10	12	9	23	19	-14	7	15	8	21
		r	9	-2	12	19	18	9	10	16	11	18	-6	9	13	12	20
Melamine; cotton fabric																	
M	$1.62 \pm 0.02 \times 10^6$	i	-7	-4	1	-3	3	-1	-4	3	3	5	-4	-1	1	0	2
		r	-3	-5	-2	3	3	-6	-5	-10	0	4	-5	1	0	3	3
Unsaturated polyester; cotton fabric																	
F	$0.71 \pm 0.02 \times 10^6$	i	-5	-3	16	19	19	-9	-20	-7	8	-31	-7	1	16	3	5
		r	-6	-5	14	16	16	-5	-4	2	13	-20	-26	7	4	7	16
H	0.67 ± 0.02	i	-10	-12	-5	10	-5	-12	1	-10	-9	-11	-11	-11	-10	-4	-3
		r	-12	-11	-7	5	0	-10	-10	-10	-11	-7	-12	1	-7	-3	2
N	0.45 ± 0.01	i	-14	-21	-6	1	-1	-48	-46	-39	-47	-48	-30	-30	-35	-25	-26
		r	-17	-16	-8	-1	-1	-29	-29	-37	-34	-31	-16	-23	-14	-20	-23
Unsaturated polyester; glass fabric																	
E	$1.81 \pm 0.04 \times 10^6$	i	-4	-5	-18	-22	3	-12	-32	-40	-41	-37	-10	-10	-10	-16	-11
		r	-9	-5	-4	-18	-3	-8	-25	-32	-41	-33	-2	0	-17	-2	-11
X	1.68 ± 0.01	i	4	4	0	4	7	5	7	4	3	10	5	8	5	8	-4
		r	8	9	1	3	28	5	5	0	3	8	4	17	-3	7	8
Y	1.44 ± 0.02	i	-5	2	-2	0	5	-2	3	1	-1	2	-3	1	1	-1	4
		r	-3	-1	-4	1	6	4	2	0	-6	-1	0	-2	-4	0	10
AA	1.82 ± 0.05	i	-14	-20	1	-5	-5	-23	-26	-6	-13	-14	-14	-9	-10	-10	-4
		r	-8	-9	9	-3	6	-28	-9	-6	-14	-11	-12	-8	-9	-3	1
AB	2.86 ± 0.02	i	-7	-7	-9	-9	-1	-9	-8	-18	-4	-6	-7	-3	-1	-2	-6
		r	-11	-12	-7	-3	-5	-11	-5	-9	-6	-5	-8	-4	-3	-5	-3

[1]Each value is average for six specimens. Accompanying plus or minus value is standard error.

[2]i, tested immediately; r, tested after reconditioning for 7 days at 77° F and 50-percent relative humidity.

[3]Each value is based on average for four specimens.

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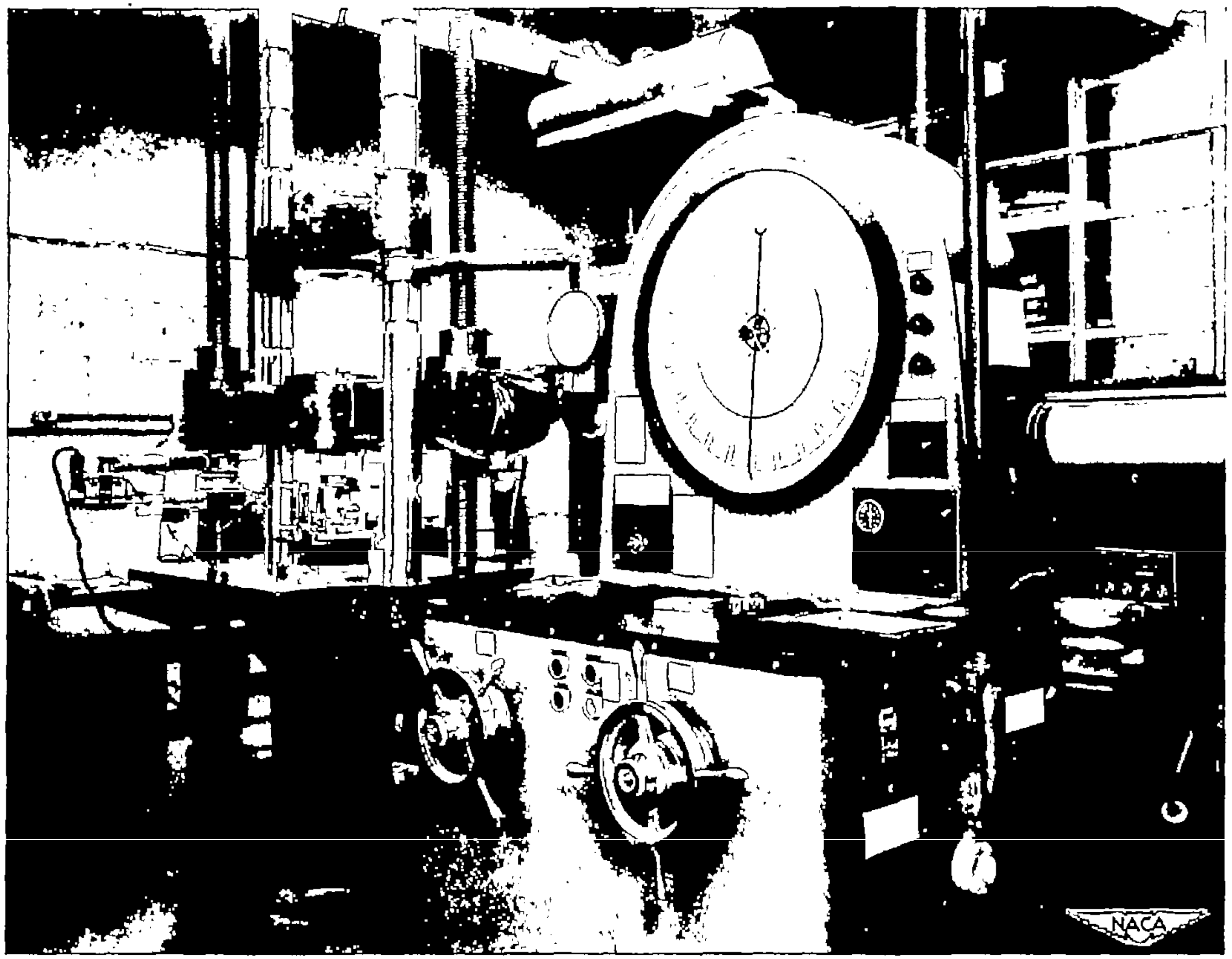


Figure 1.- Hydraulic universal testing machine with electrical-mechanical extensometer and autographic recorder.

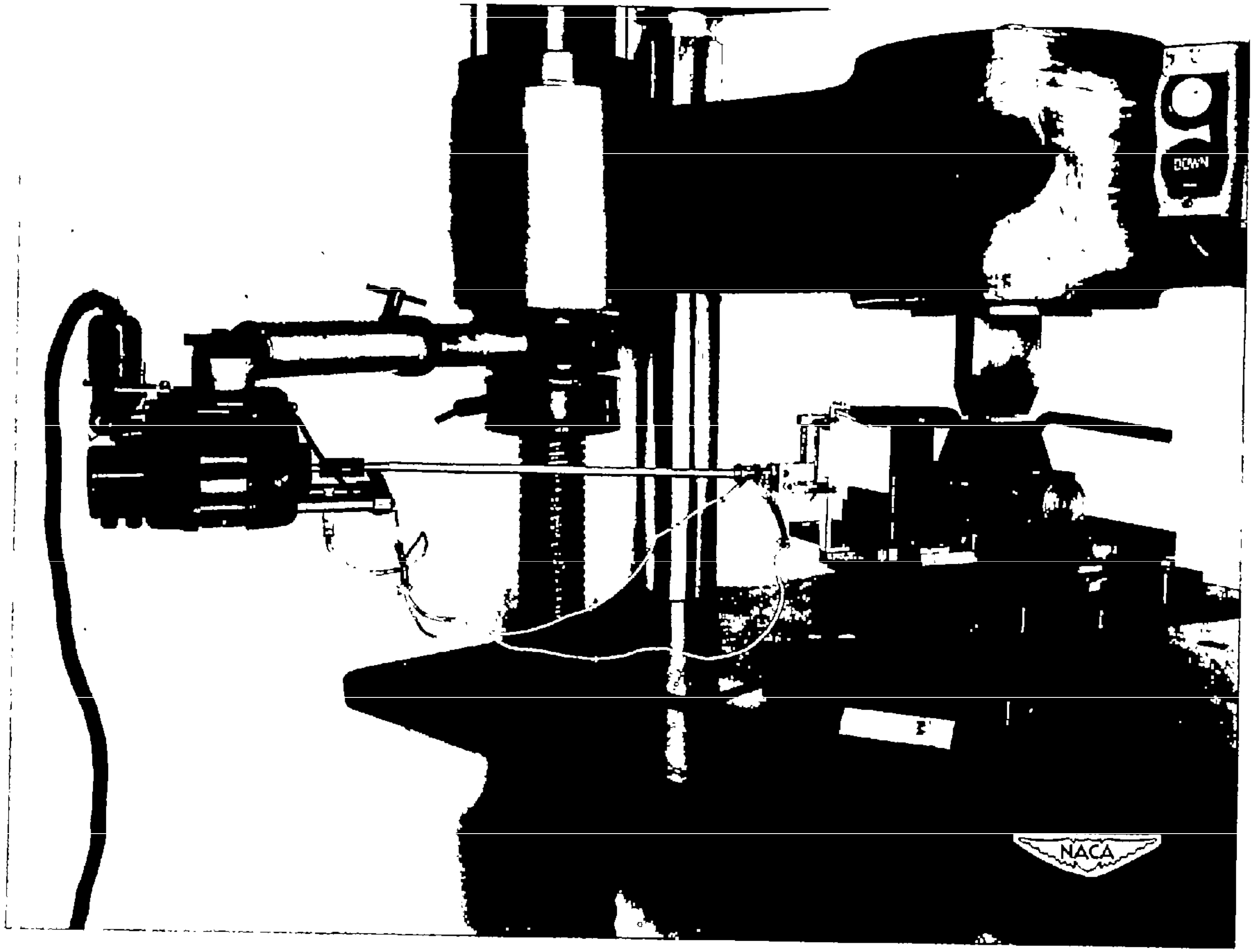
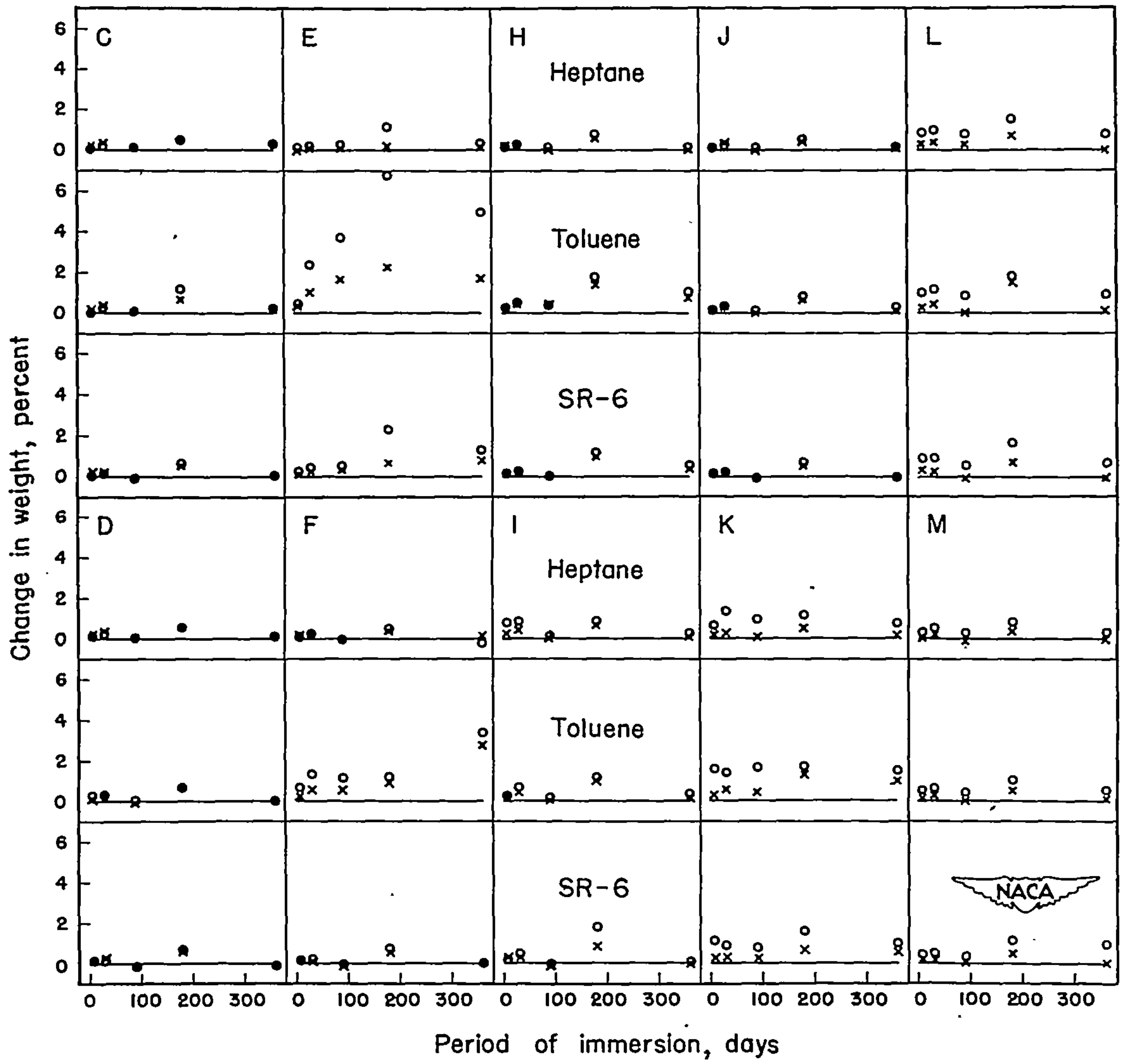


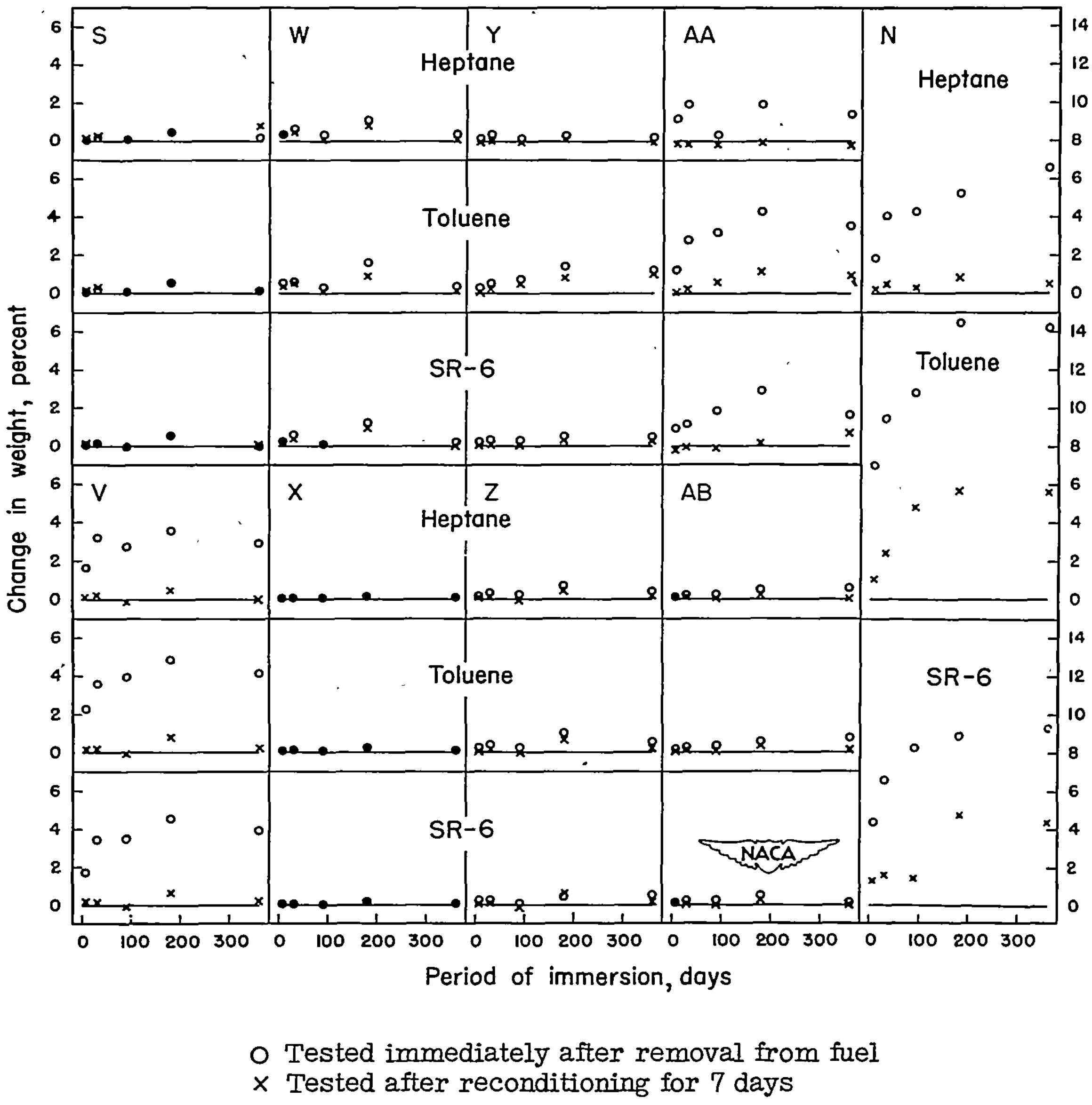
Figure 2.- Adjustable-span flexural jig and extensometer.



o Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

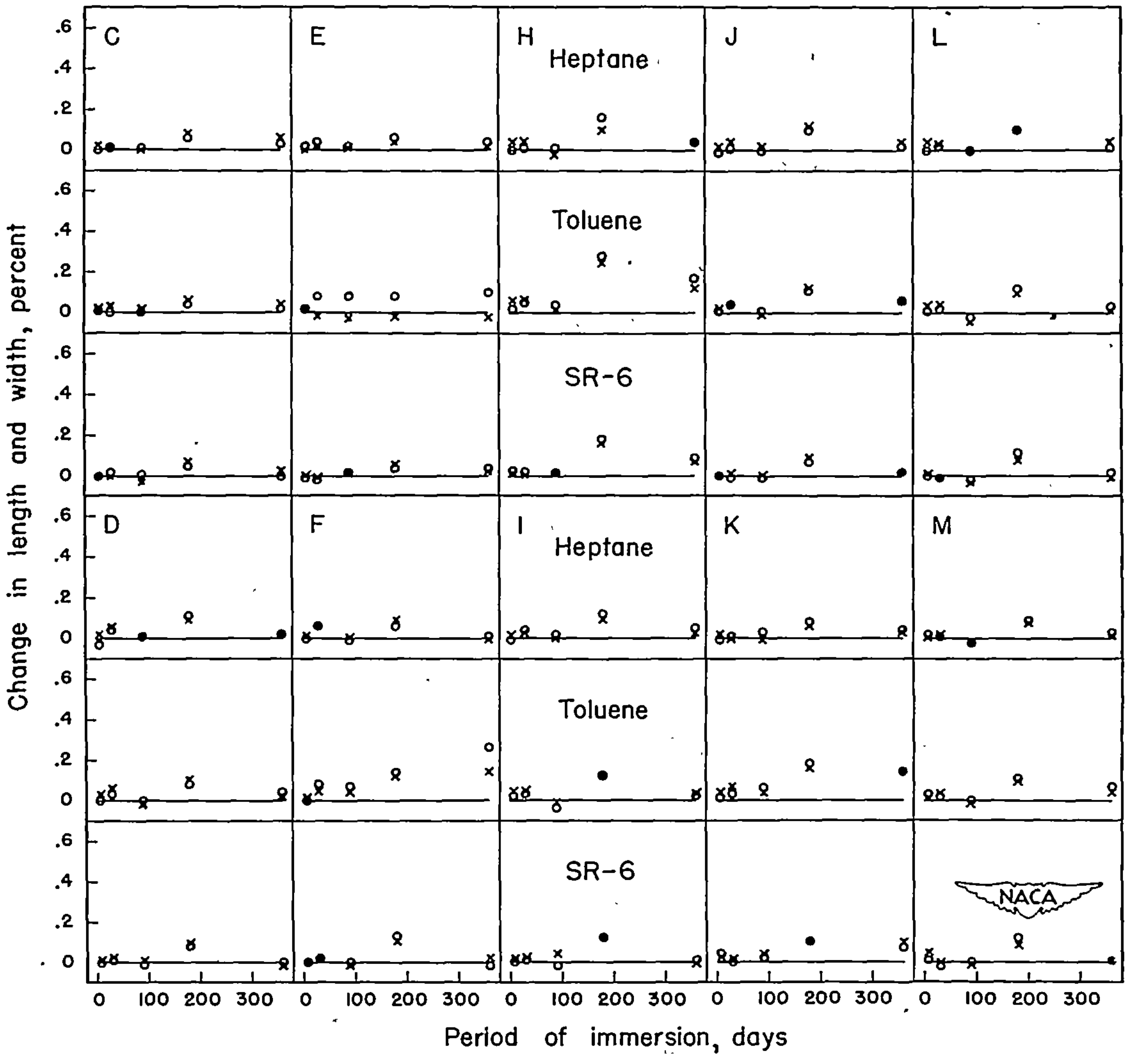
(a) Laminates C, D, E, F, H, I, J, K, L, and M.

Figure 3.- Changes in weight of laminates in continuous fuel-immersion tests. For description of laminates, see table I.



(b) Laminates S, V, W, X, Y, Z, AA, AB, and N.

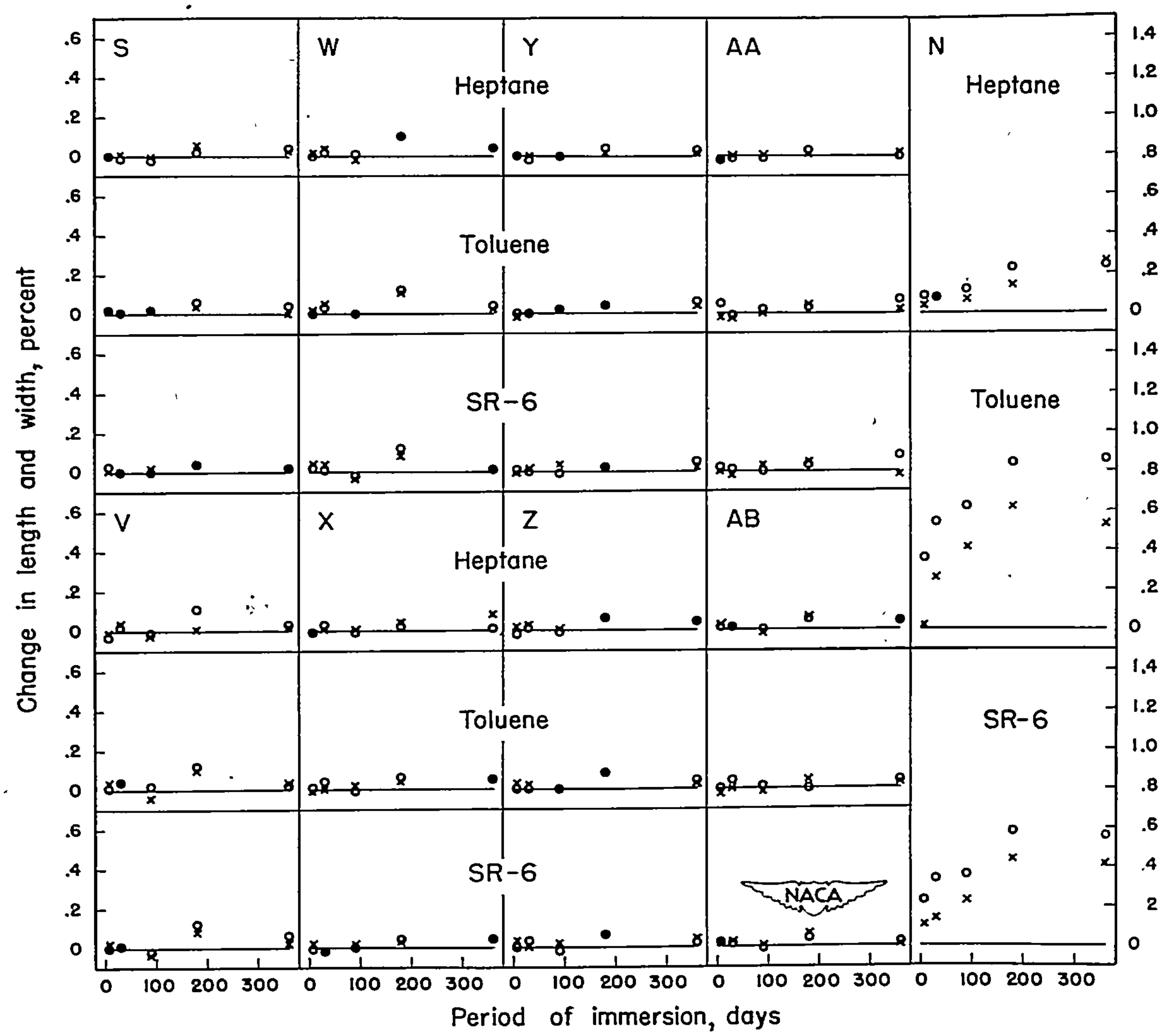
Figure 3.- Concluded.



o Tested immediately after removal from fuel
x Tested after reconditioning for 7 days

(a) Laminates C, D, E, F, H, I, J, K, L, and M.

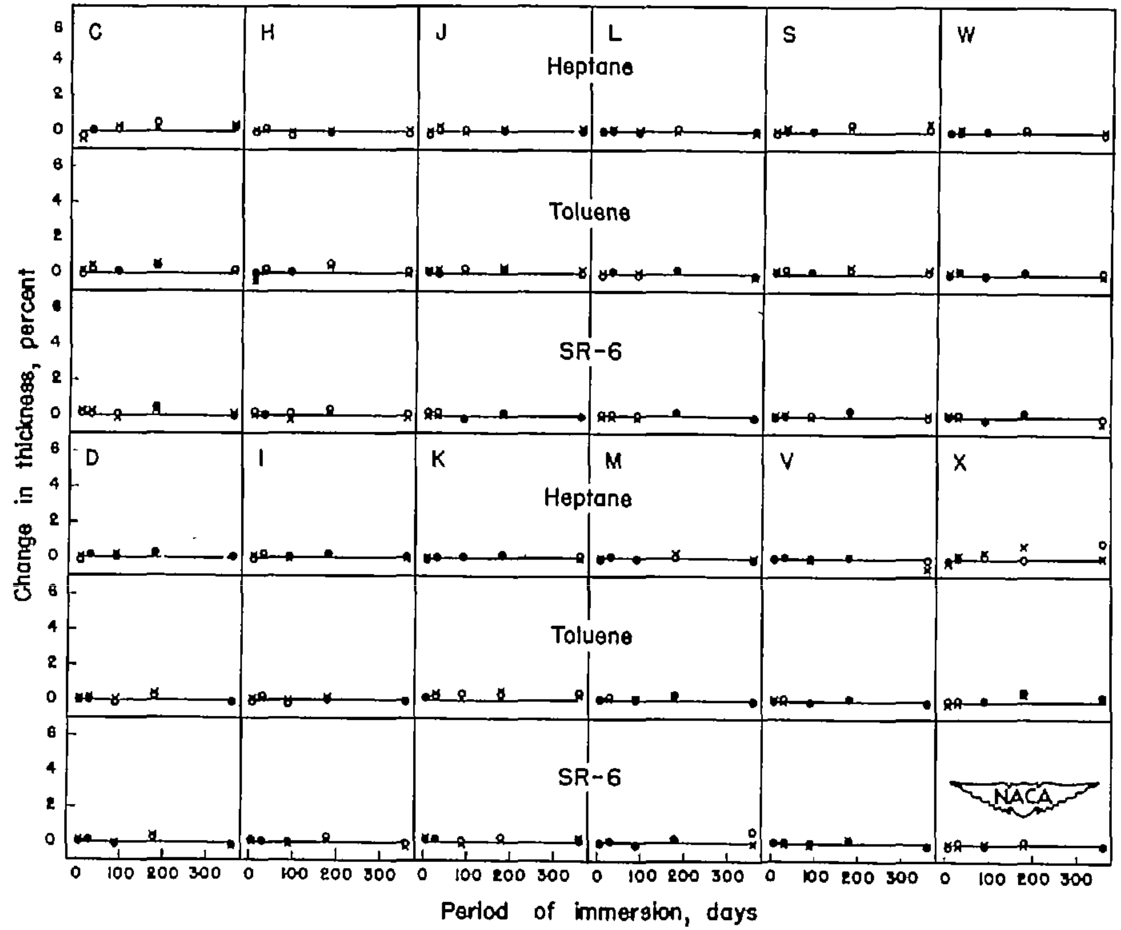
Figure 4.- Changes in length and width of laminates in continuous fuel-immersion tests. For description of laminates, see table I.



o Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(b) Laminates S, V, W, X, Y, Z, AA, AB, and N.

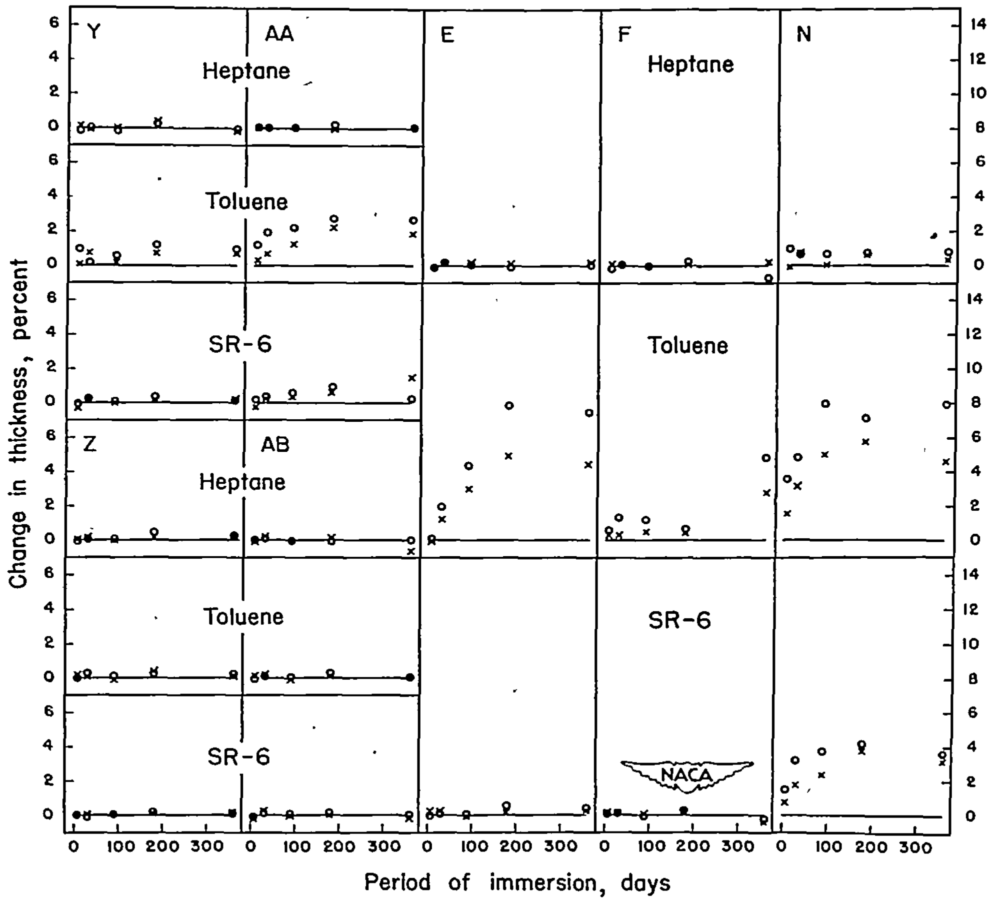
Figure 4.- Concluded.



O Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(a) Laminates C, D, H, I, J, K, L, M, S, V, W, and X.

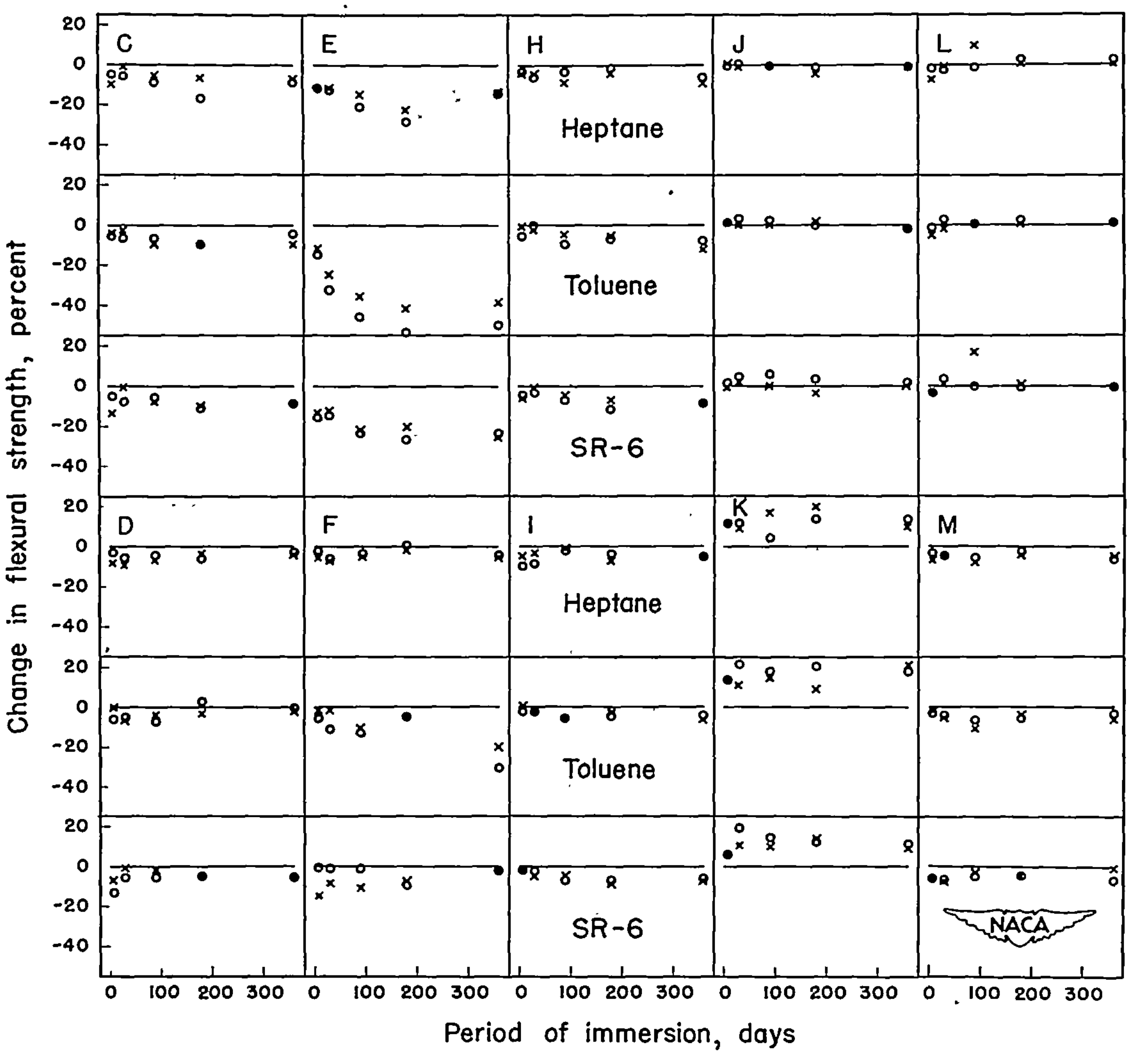
Figure 5.- Changes in thickness of laminates in continuous fuel-immersion tests. For description of laminates, see table I.



O Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(b) Laminates Y, Z, AA, AB, E, F, and N.

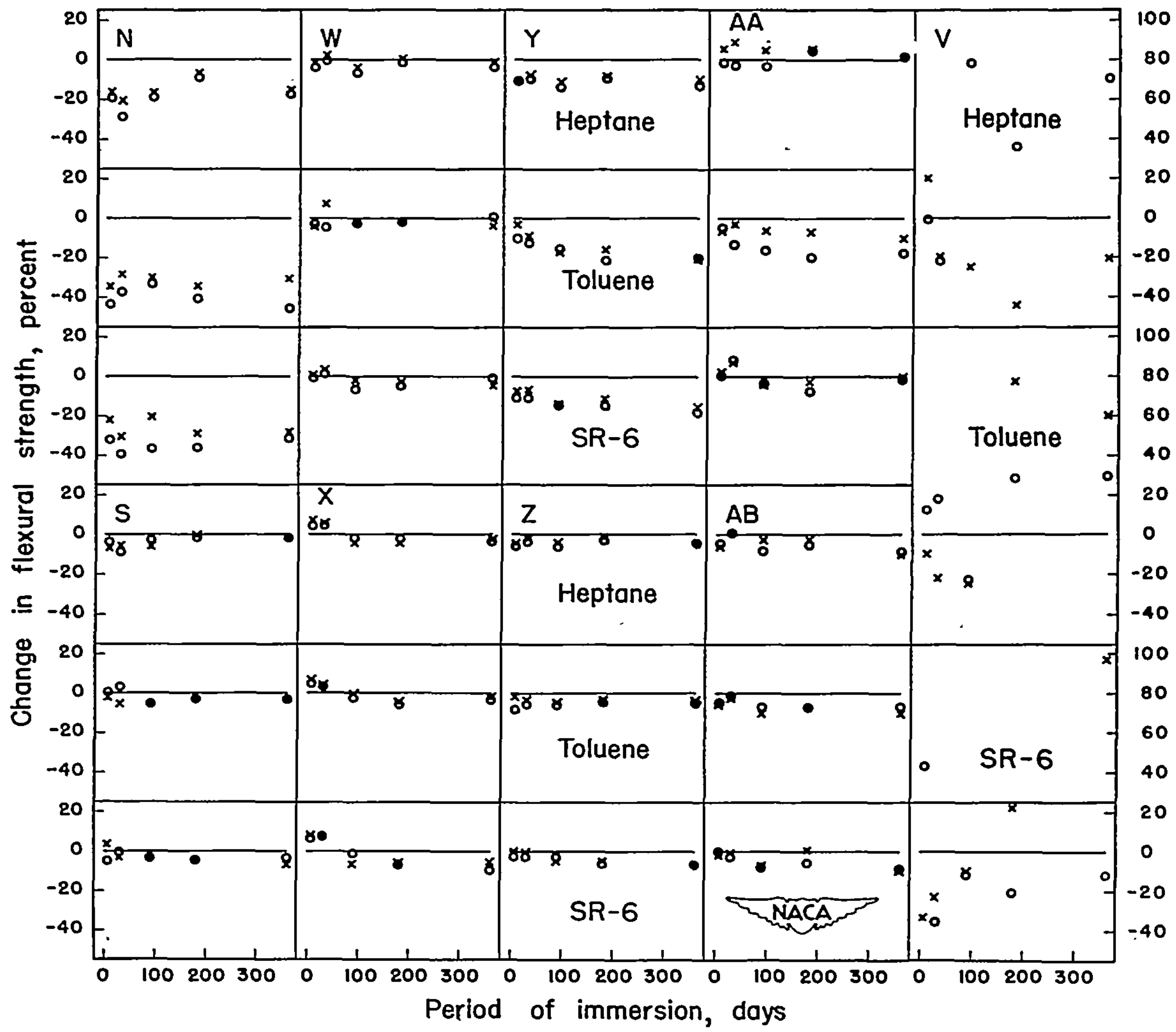
Figure 5.- Concluded.



O Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(a) Laminates C, D, E, F, H, I, J, K, L, and M.

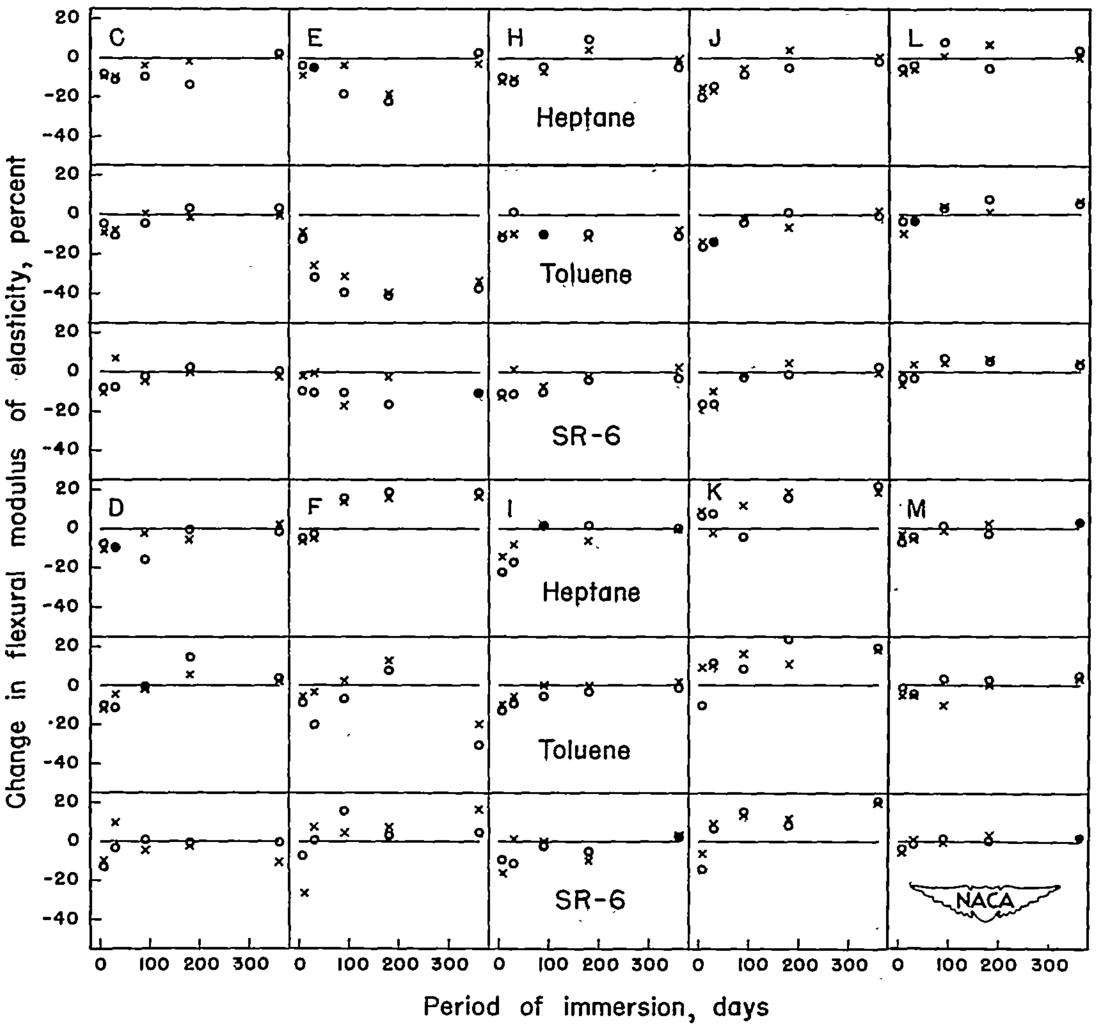
Figure 6.- Changes in flexural strength of laminates in continuous fuel-immersion tests. For description of laminates, see table I.



O Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(b) Laminates N, S, W, X, Y, Z, AA, AB, and V.

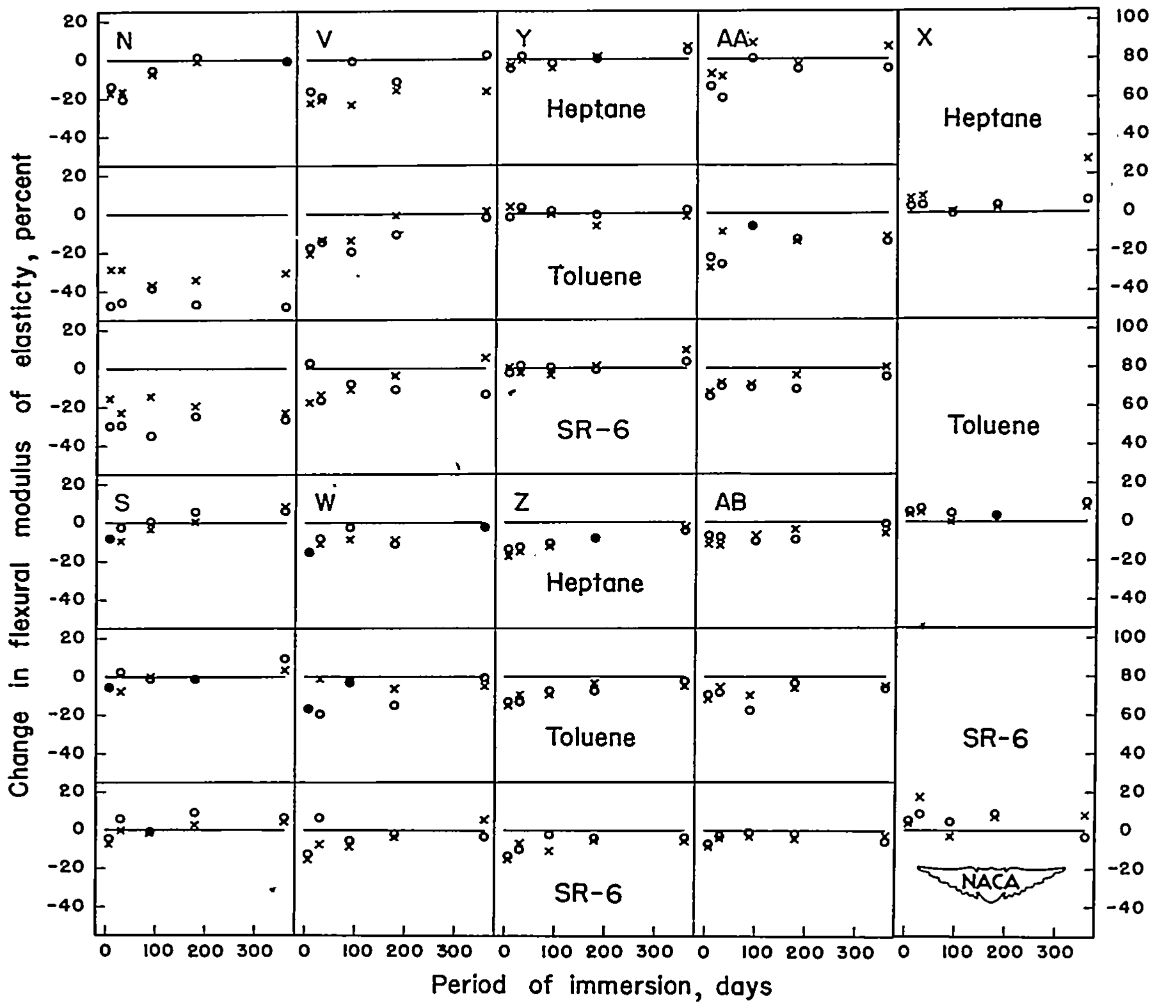
Figure 6.- Concluded.



O Tested immediately after removal from fuel
X Tested after reconditioning for 7 days

(a) Laminates C, D, E, F, H, I, J, K, L, and M.

Figure 7.- Changes in flexural modulus of elasticity of laminates in continuous fuel-immersion tests. For description of laminates, see table I.



O Tested immediately after removal from fuel
× Tested after reconditioning for 7 days

(b) Laminates N, S, V, W, Y, Z, AA, AB, and X.

Figure 7.- Concluded.

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